IEEE SW Test Workshop

Semiconductor Wafer Test Workshop

June 9 - 12, 2013 | San Diego, California

New Generation of Probe Alloys

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Overview

Increases in overall wafer size coupled with ever decreasing feature size places tremendous pressure on optimizing the materials used for semiconductor test probes.

This is especially true as the test environment pushes to smaller diameter probes required by today's micro and nano revolution.

It is well known that material characteristics such as electrical conductivity and hardness play a key role in probe performance.

However, other material properties (temper, formability, etc.) may also influence performance, reliability and life cycle cost of the probes.

Presentation Outline

- Semiconductor History
  - Impact of more powerful IC's
  - Product evolution demanding smaller probes
- Relevant Material Properties
  - Spring Constant
  - Hardness
  - Conductivity - CCC Performance
  - Formability
- Important Factors Affecting Lifetime
  - Starting temper & Forming
  - Prolonged thermal exposure

Quick Review of IC History

IC Evolution

- **Overall wafer size getting larger**
  - More dies per wafer
  - More complex testing protocol

- **Feature size getting smaller**
  - Maintain function - smaller components
  - Increased function - more power, higher test currents
  - Higher test temperatures

Power Consequences

- Transistor count increases with Moore's law
  - Doubles approximately every 2 years
- Higher transistor count means more power
- More power means test probes must carry more current
- More current means probes run hotter

Test Probes

Evolution of Vertical Probe Size

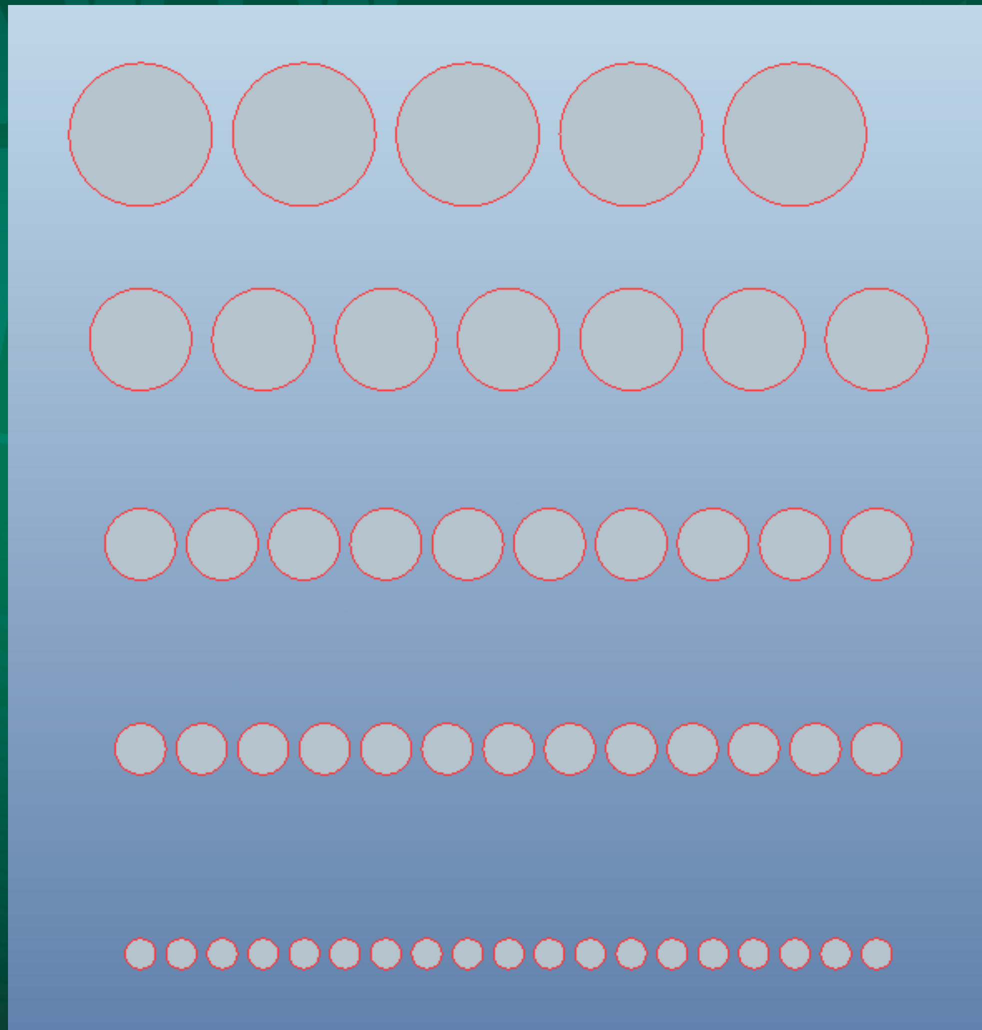
1978 – 0.178 mm (.007")

1985 – 0.127 mm (.005")

2000 – 0.089 mm (.0035")

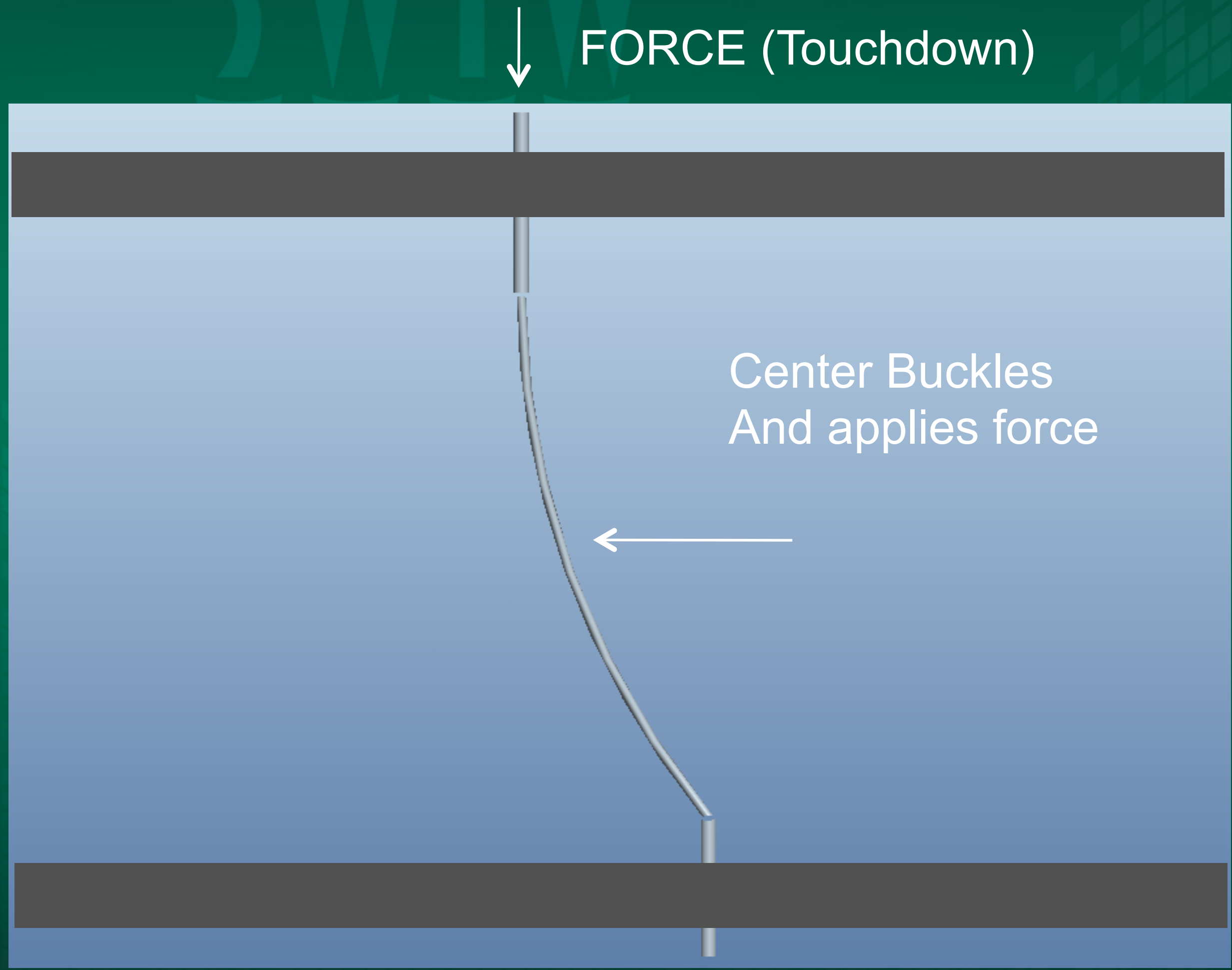
2009 – 0.064 mm (.0025")

2013 – 0.038 mm (.0015")

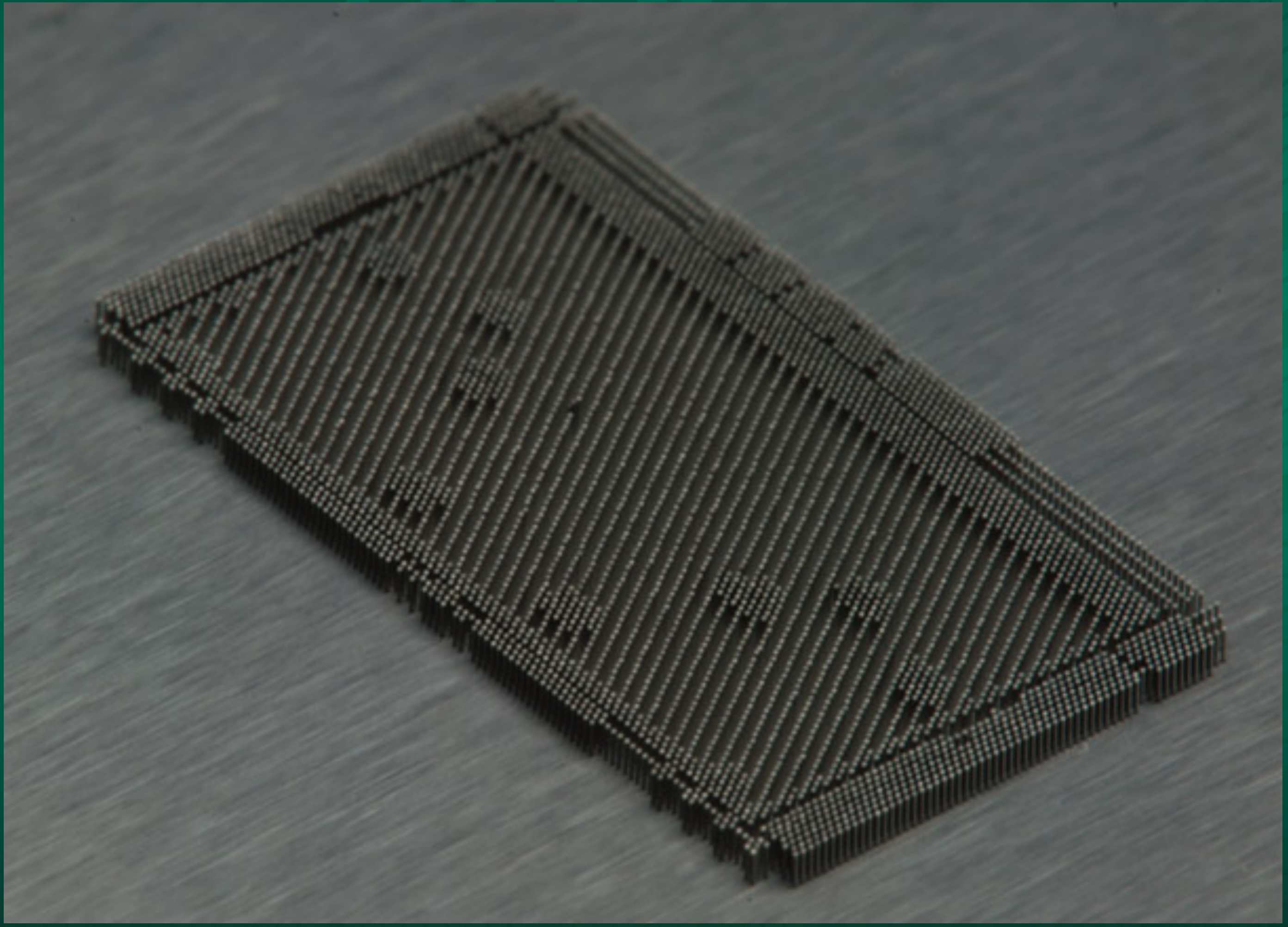


Single Probe in Card

Single Probe



Fully Populated Card



Array can approach 10,000 pins

Size Consequences

- Chip Real Estate is at a premium
- Higher density of smaller features
- Result- pad sizes must shrink

- Since probe tips must contact the pads
- Probe diameter/ tips must also get smaller
- Smaller diameter means probes run hotter

Noble Metal Alloy Options

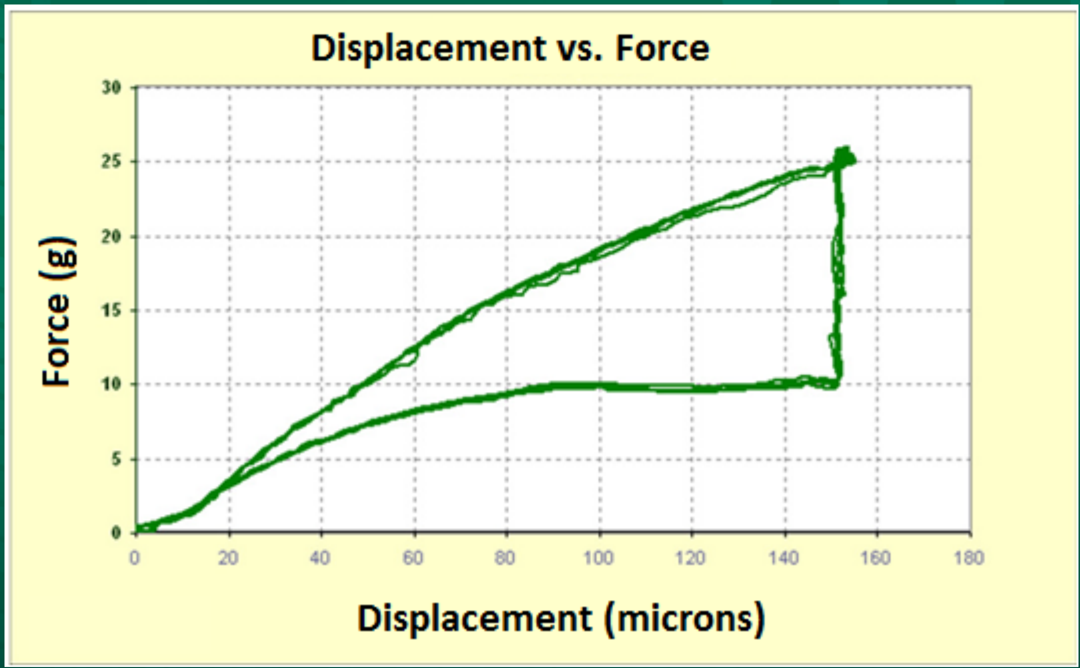
Alloy Properties

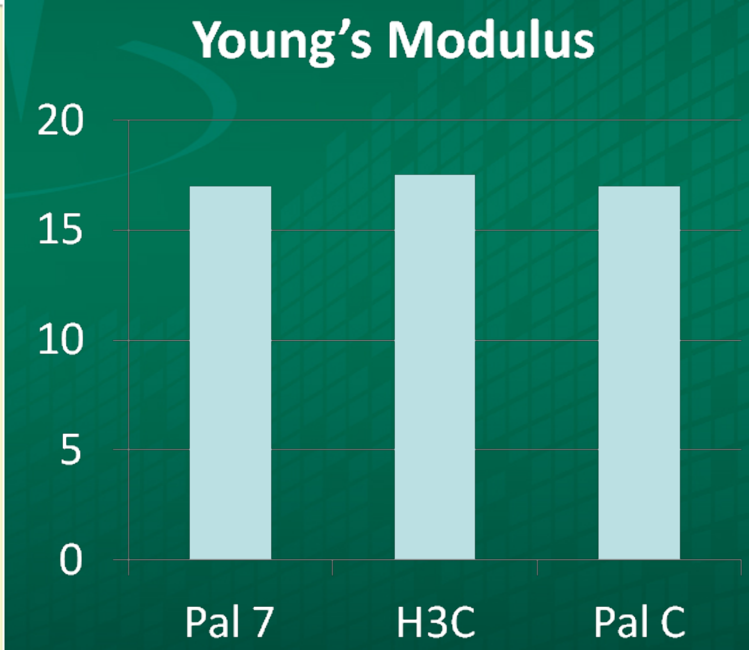
(Nominal)

Properties	Paliney 7 (Pd-Ag-Cu-Pt-Au)	Paliney H3C (Pd-Ag-Cu)	Paliney C (Pd-Ag-Cu)
HT Conductivity (%IACS)	5.5	14.5	16.5
Annealed UTS Hardness	120 ksi 230Hv	170 ksi 260Hv	125 ksi 260Hv
Heat Treated UTS Hardness	180 ksi 380Hv	250 ksi 475Hv	190 ksi 385Hv
Benefits	High nobility, Low C_R	High Conductivity High Hardness, Low C_R	High Conductivity, Low C_R

Material Properties

- **Spring Constant – Affects Gram Force**
  - Controlled by Elastic Modulus and Geometry





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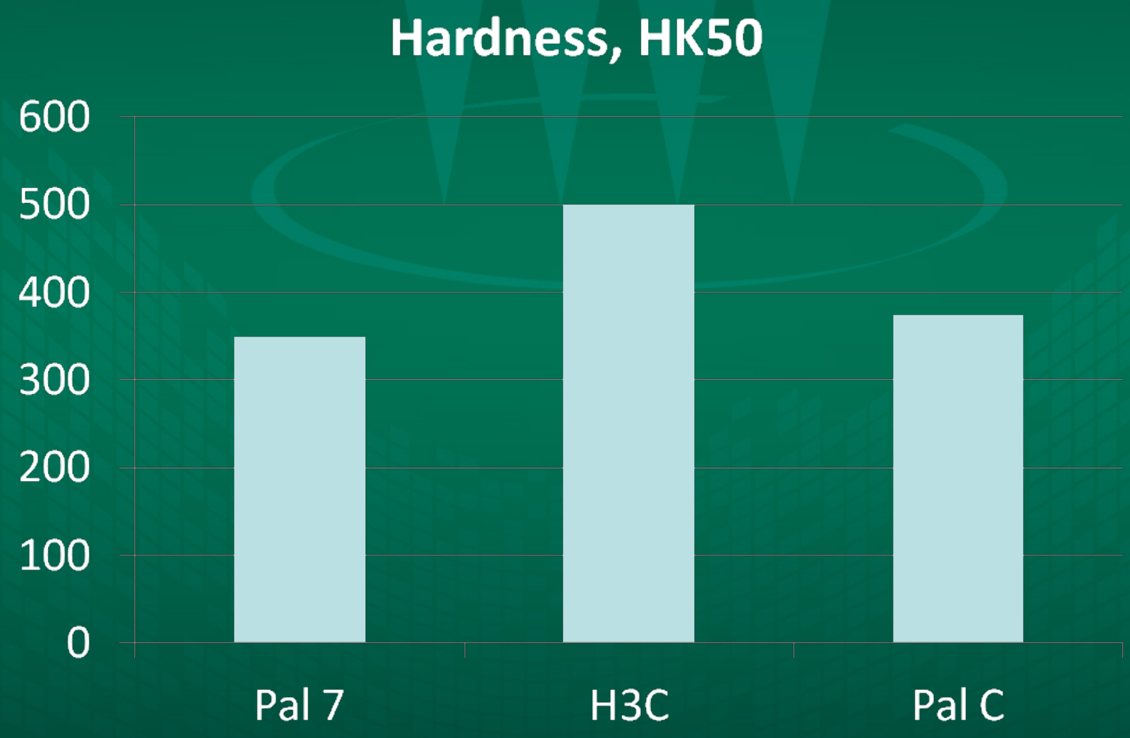
Material Properties

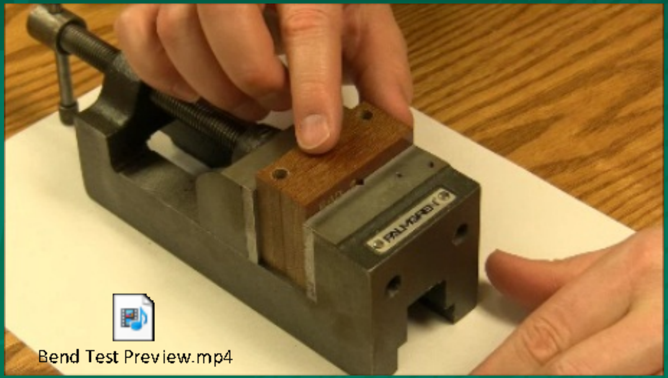
- **Hardness – Affects wear / point life**



Material properties -Formability

Measurement Techniques

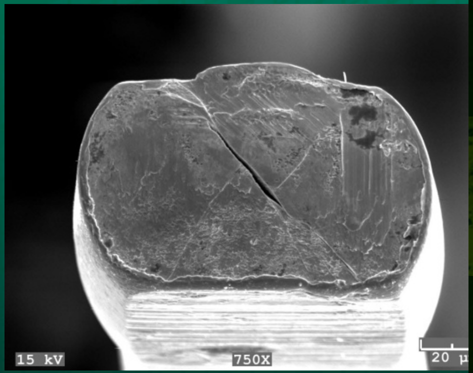
– Repeated 90° bends
  - # of Bends
  - Modified protocol
    – Improved reproducibility

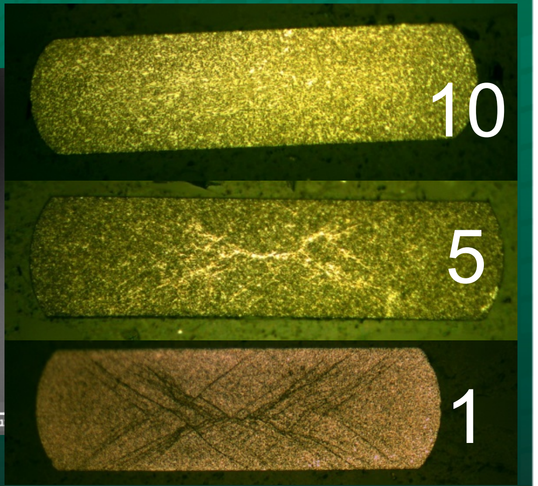


– Roll to Ribbon
  - Rated on a scale 1-10

1 =Open Cracks

10 =No Visible Strain Lines

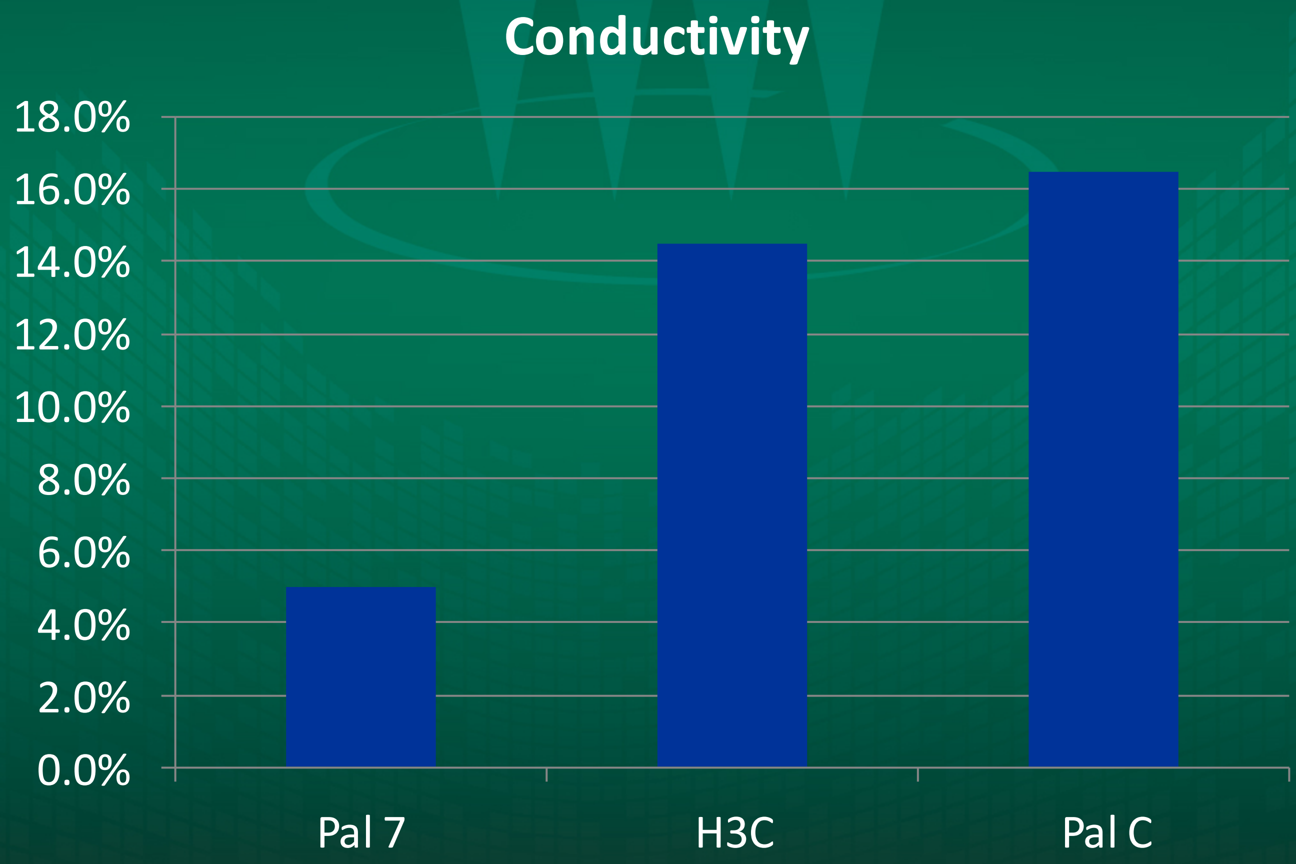




Results of Formability Tests

Material Properties

- **Electrical Conductivity   %IACS**



CCC Testing

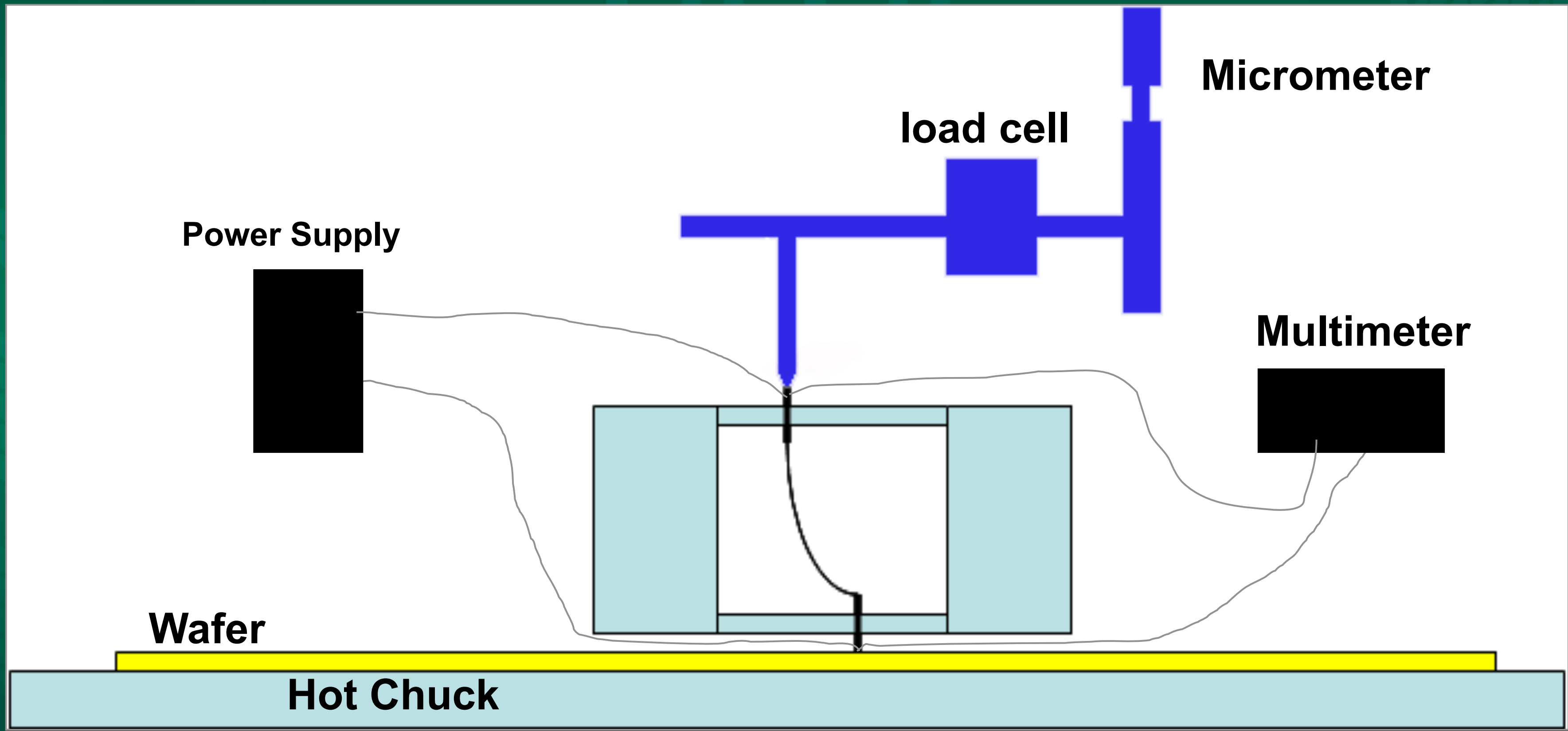
Current Carrying Capacity (CCC)

Methodology

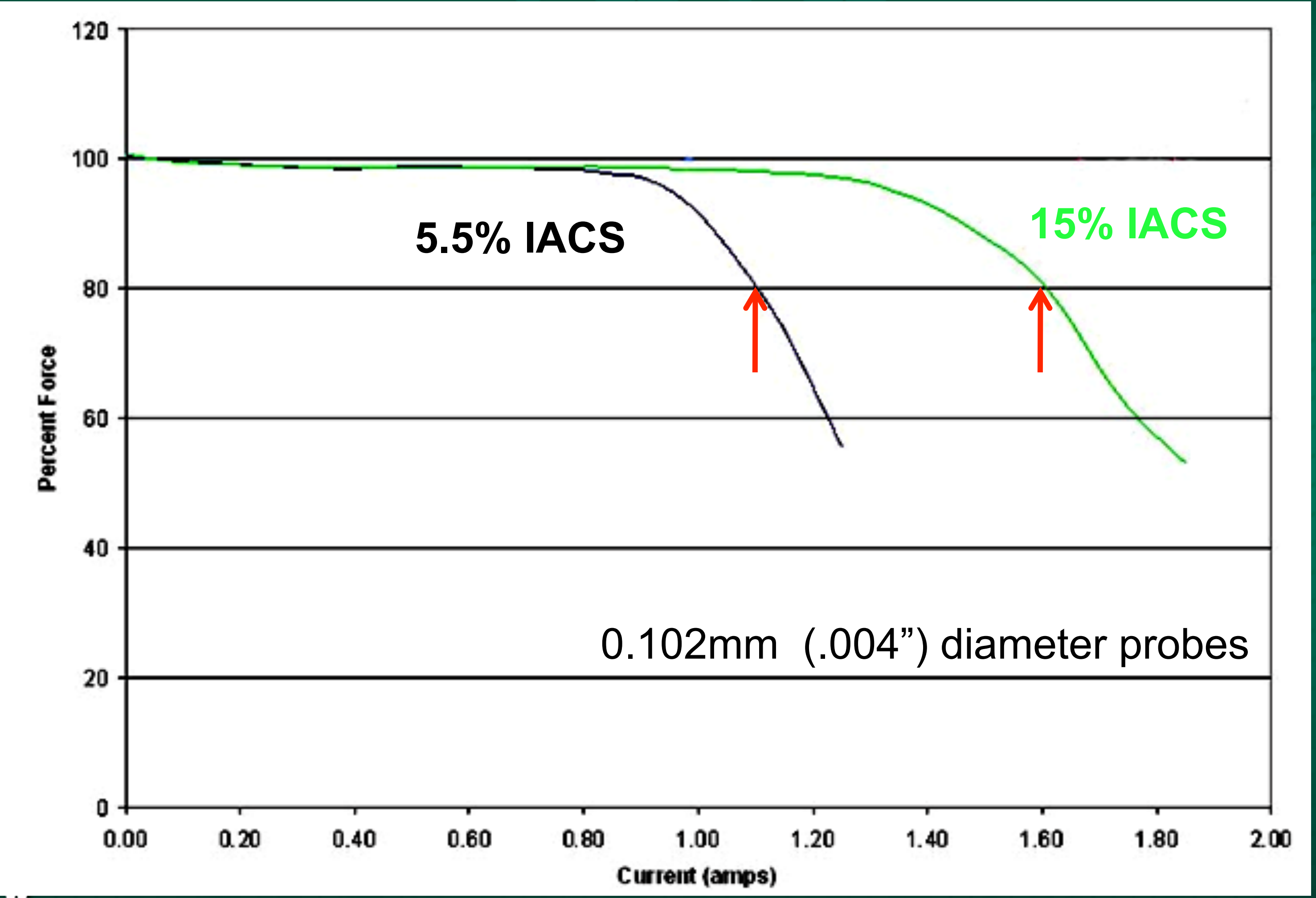
Load probe to recommended overdrive
Measure gram force
Apply current to the probe – to reach steady state
Turn current off
Allow the probe to cool
Measure gram force of Probe at the end of each current cycle
Incrementally increase current
Repeat process until gram force is less than 80% of initial gram force

CCC defined as the current level where probe force is 20% lower than the initial force

CCC test cell



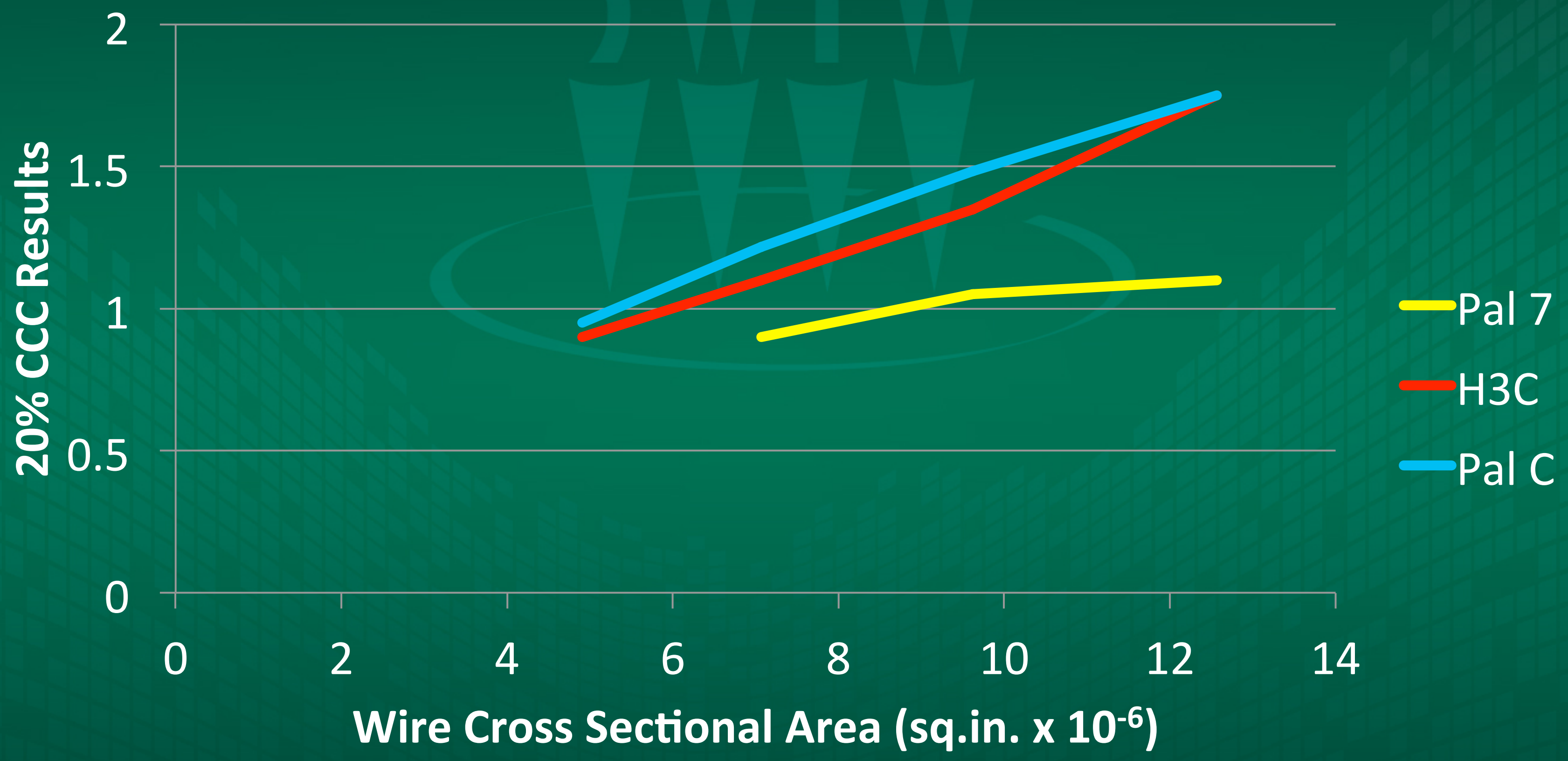
Effect of Electrical Conductivity



Alloy CCC Data

Probe Size	Paliney 7 (5.5% IACS)	Paliney H3C (14.5% IACS)	Paliney C (16.5% IACS)
4.0 mil	1.10 A	1.75A	1.75A
3.5 mil	1.05A	1.35A	
3.0 mil	.90A	1.10A	
2.5 mil		0.95A	0.95A

Alloy CCC Data



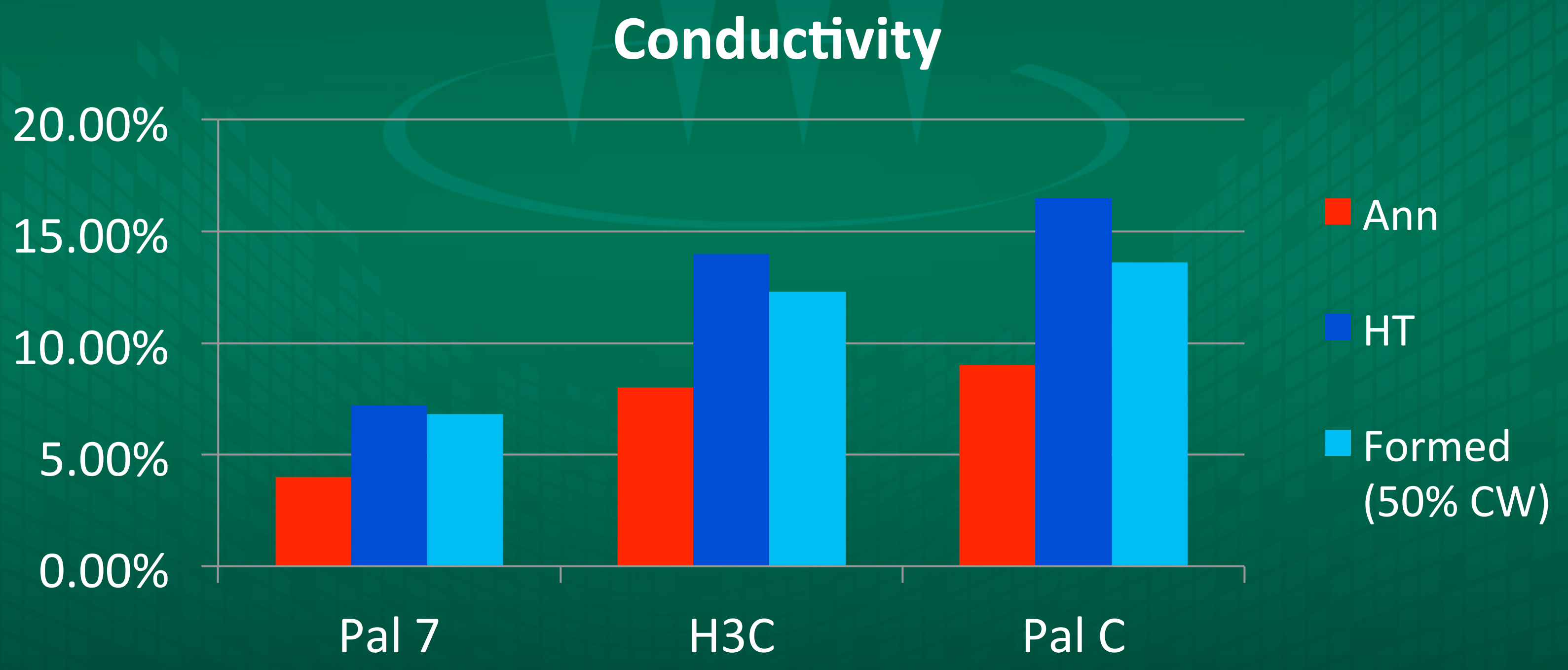
Factors Affecting Probe Lifetime

- **Initial Material Properties are altered by:**
  - Probe Forming
  - Prolonged Thermal Exposure

- **Re-evaluate properties in process**

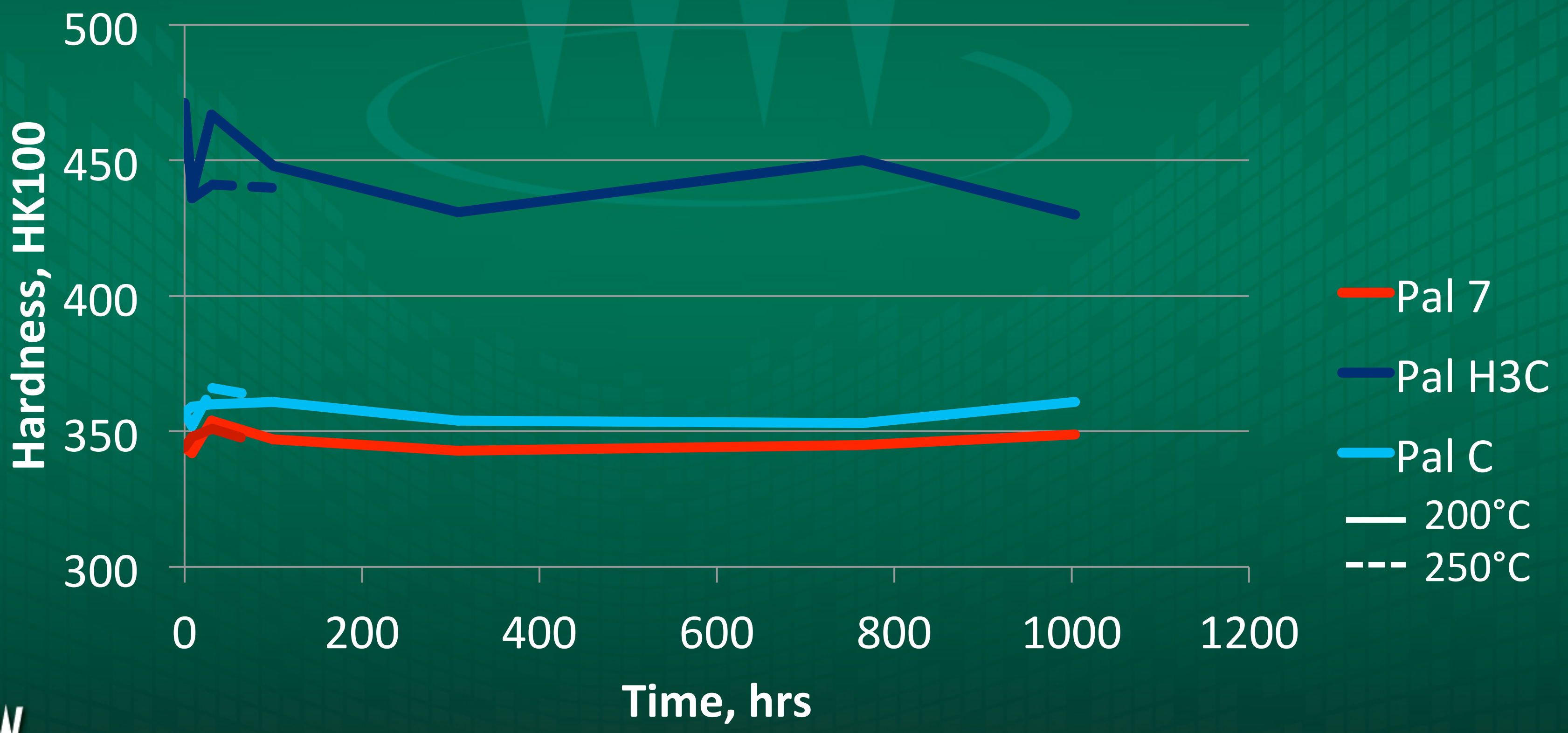
Factors Affecting Probe Lifetime

- Starting temper and Affect of cold work (forming)



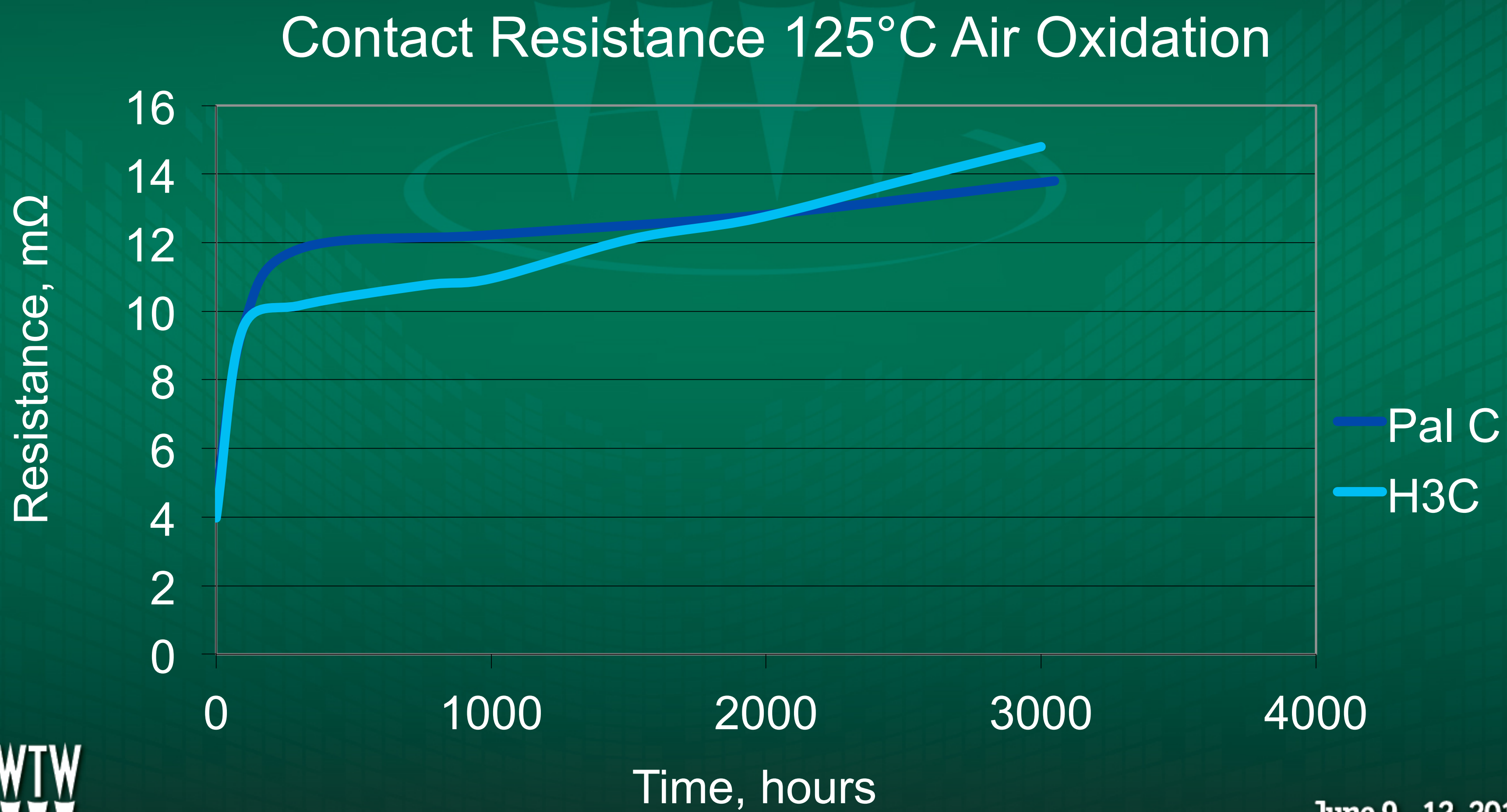
Factors Affecting Probe Lifetime

- **Prolonged thermal exposure**
  - Alloy Softening - 200°C



Factors Affecting Probe Lifetime

- **Prolonged thermal exposure**



Conclusions

- **Current Market demands optimized materials**
  - Electrical Conductivity and Hardness play key role in determining material performance.
- **Reliability and life cycle cost also determined by:**
  - Starting Temper
  - Testing Environment
  - Probe Forming

Conclusions

- **Notable DNI Materials for Probes**
  - Paliney 7
    - Industry Benchmark – Low Conductivity
  - Paliney H3C
    - High Hardness and Conductivity, Lower Formability
  - Paliney C
    - Hardness of Paliney 7
    - Higher conductivity than H3C.
    - Increased Formability

Acknowledgements

The authors would like thank Joey Wu of MPI for performing and sharing the ccc tests and the spring rate measurements

We would also like to thank Scott Marquis and Dave Birdsall from our lab for all their assistance during the development and testing of these new alloys

Questions ?

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Thank you!

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